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Introduction

Biochemistry is a fascinating subject that deals with the chemical language of life, be it human, animal, plant, or microorganism. No other science subject has as much application as biochemistry to the disciplines of medicine, health, veterinary, agriculture, bioengineering, and technology. Biochemistry interfaces with biology and chemistry and is concerned with the chemical processes that take place within living cells. The ultimate goal of biochemistry is to describe the phenomena that distinguish the living from non-living in the language of chemistry and physics. Its object is not only to probe into the structures of the molecules found in living organisms, but also into their overall mode of reactions, both separately and in combination.

Researchers in biochemistry use specific techniques native to biochemistry, but increasingly combine these with techniques and ideas from genetics, molecular biology and biophysics. There has never been a hard-line between these disciplines in terms of content and technique, but members of each discipline have in the past been very territorial; today the terms molecular biology and biochemistry are nearly interchangeable.

Science and scientific research have been growing at a faster rate during recent years. In India at present around 75,000 students are enrolled in research and nearly 11,000 are awarded PhDs every year, of which 50 percent are from science and technology disciplines. The number of PhDs produced might be useful as an indicator of the growth of the science and technology sector. It is surprising to find that a large fraction of doctoral theses do not result in any significant research publication, in journals of consequence. Indeed even as the number of doctoral degrees awarded in science has increased, the number of papers from India in SCI indexed journals has remained stagnant.

Theses and dissertations reflect the scholarly communication process. Scientometrics and citation characteristics of dissertations like, the subject fields of dissertations, the number of citations and their distribution by type of source, years, and by number of authors etc., have been studied with a view to identify the basic features of the scholarly communication process in different fields of study. The characteristics of cited sources that appear in the bibliographies of dissertations have been used not only

to help identify core journal titles in specific subject field but also that can be used in collection management decisions and scientometric evaluations.

The purpose of the present study is to determine the bibliometric characteristics of the biochemistry research in the University of Kerala, India, including subject wise break-up, bibliographic forms of cited documents, most cited journals, collaboration in authorship, etc. In order to study the research trend of biochemistry in the University of Kerala, a total of 168 doctoral dissertations awarded between 1966 and 2007 at the Department of Biochemistry of University of Kerala are used as a source.

University of Kerala

The University of Kerala is the mother university of its state, and has been at the centre of higher education activity in Kerala since its inception. The university has sixteen faculties and forty-one departments of teaching and research, with 177 affiliated colleges. The university departments offer a wide range of teaching and research at postgraduate, MPhil, and PhD levels.

Every year the number of PhDs awarded has steadily increased. In 1960, only one PhD was awarded, whereas the number rose to 3,221 in 2008.

Department of Biochemistry

The Department of Biochemistry has a distinguished tradition of more than four decades of research and teaching on various aspects of biochemistry. The department started in 1961 as a unit of chemistry. A separate division of biochemistry was formed within the Department of Chemistry in 1964 and became an independent Department of Biochemistry in 1970. Major areas of research include the biochemical basis of diseases such as atherosclerosis, diabetes, and filariasis, as well as micronutrients, environmental biochemistry, cellular biochemistry, and alcoholism.

It is one of the few early departments in the country which started postgraduate teaching and research in biochemistry. During the last four decades, more than 330 MSc, 50 MPhil, and 173 doctoral students have taken their degrees from the department and more than 750 papers have been published in various national and international journals in biochemistry. The department has been in the forefront of academic activities, including national and international conferences, workshops, and short term course, apart from providing sophisticated biochemical testing services, particularly for genetic diseases.

Review of Related Studies

A large number of scientometric studies have been conducted on dissertation citations in various subject fields in India and abroad. The present study focuses on the citation characteristics of biochemistry theses in the University of Kerala.

Ardanuy, Urbano, and Quintana (2009) in their paper studied the situation of research on Catalan literature between 1976 and 2003 by carrying out a bibliometric and social network analysis of PhD theses defended in Spain. An analytical study of master of library and information science dissertations at the University of Maiduguri, Nigeria was conducted by Aliyu and Abba (2009). Citation analysis of PhD dissertations in plant biology and zoology at Southern Illinois University, Carbondale, was done by Nabe and Imre (2008). Vallmitjana and Sabate (2008) carried out a bibliometric study on the citations in the chemistry PhD dissertations to ascertain what types of document are the most frequently used in the research process, the most frequently consulted journals and obsolescence rate of the journals.

Kuruppu and Moore (2008) conducted a study on the citations of doctoral dissertations submitted in nine agriculture and biological science subject fields at Iowa State University (ISU) from 1997-2006. 27 Library and information science dissertations submitted to the University of Pune between 1982 and 2005

were studied by Chikate and Patil (2008). Keat and Kaur (2008) conducted a study in the same field in Malaysia. Sudhier Pillai (2007) in his citation study comprised 690 journals containing 11412 references collected from 71 doctoral theses awarded by the Indian Institute of Science, Bangalore during 1999-2003. Waugh and Ruppel (2004) had conducted a study of citation analysis of dissertations, thesis and research paper references of Southern Illinois University Carbondale (SIUC).

Several studies on theses citation have been done by different authors in various subject fields. Sam and Tackie (2007) in information studies; Chrzastowski and Joseph (2006) in engineering; Raza and Zarrin (2004), Srivastava (2002), Gooden (2001) carried out a citation analysis study of dissertations in chemistry; Tonta and Al (2006), Mahapatra, Sahoo and Jyotshna (2004) in LIS; Krishna and Kumar (2004) studied agriculture and veterinary sciences theses; Biradar and Thippeswamy (2004) studied paediatric dissertations; Haycock (2004), Beile, Boote and Killingsworth (2004) and Okiy (2003) investigated the use of dissertation citation analysis in education; Naidu, Chauhan and Prasher (2003) in biological science; Gobbur, Kamble and Jange (2003) in English; Chandrakumar and Sritharan (2003) in Sanskrit; Cano and others (2003) in mathematics education and Mangla and Seema (2002) conducted a study on economics.

The review of related studies on the doctoral dissertation citations showed that there were no quantitative study on biochemistry has been conducted so far. Hence the present study.

Objectives of the Study

The objective of the present study is to examine the PhD theses awarded from the Department of Biochemistry up to 2007, in order to determine the following:

- To discover trends in biochemistry research
- To discover the subject distribution of theses and the main areas of research.
- To discover what format of materials re-used by doctoral students in biochemistry
- To discover the most frequently cited journals in the field.
- To discover the most frequently cited books in biochemistry

Methodology

The methodology includes a literature survey and bibliometric analysis of the theses and the citations/references appended to them. The title page and bibliographies for the PhD theses have been photocopied, and demographic data about each thesis recorded. Then the task of identifying and recording information about the individual citation began.

The study focuses on the analysis of biochemistry doctoral theses awarded from the Department of Biochemistry, University of Kerala, from 1966 to 2007. There were 168 Biochemistry PhDs awarded during this period from the department. All were examined to collect data on relevant features required for the study. This study is divided into two parts. The first deals with the theses and the second deals with citation analysis. Of 168 theses, 21 were selected as samples by simple random sampling.

Analysis and discussion

The data analysis and discussion of the study are given below.

Subject-wise distribution

In order to determine the direction of biochemistry research, the theses were divided into broad subject categories, shown in Table 1. The subject categorization was done according to the 21st edition

of the Dewey Decimal Classification (DDC). This subject classification gives some idea of the relative importance of the traditional branches as well as the newly-developed specialised branches of biochemistry.

Table 1: Subject categories of theses

Sl. No.	Subject	No. of theses	Percent	Cumulative percent
1	Clinical Biochemistry	43	25.60	
2	Metabolism	29	17.26	42.86
3	Nutrition	26	15.48	58.34
4	Parasitology	22	13.10	71.44
5	Toxicology	15	08.93	80.37
6	Biochemistry	11	06.55	86.92
7	Plant biochemistry	08	04.74	91.66
8	Cancer biology	04	02.38	94.04
9	Cytology	04	02.38	96.42
10	Endocrinology	02	01.19	97.61
11	Clinical Microbiology	02	01.19	98.80
12	Enzymes	01	0.60	99.40
13	Marine biology	01	0.60	100.00
Total		168	100.00	100.00

Clinical biochemistry has the highest number of theses awarded, 43, or 25.60 percent, with metabolism and nutrition in second and third place.

Year-wise distribution

Year-wise analysis of theses reveals that the maximum contribution was made during 1993, with 16 theses. After the independent formation of the department in 1970, the lowest contributions were made in 1972 and 2003. Only one thesis each was produced during these periods. It is interesting to note that not even a single PhD was awarded in 1970, 1974, 1979, and 1983 after the independent formation of the department.

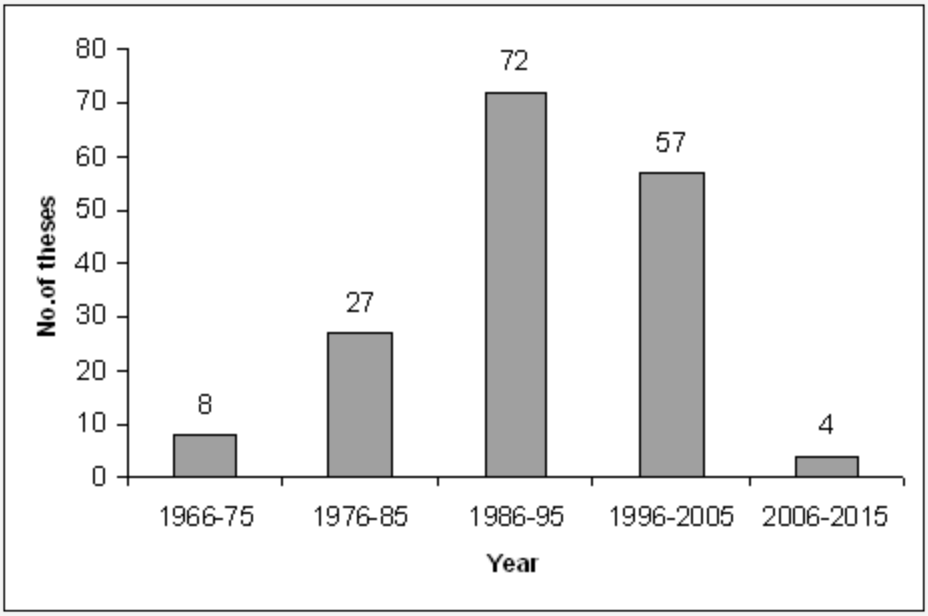


Figure 1: Year-wise distribution of theses

Figure 1 reveals that 72 theses were produced between 1986 and 1995.

Page-wise distribution of theses

Page-wise analysis of biochemistry theses is shown in Table 2.

Table 2. Page-wise distribution

Sl. No	Pages	No. of theses	Percent	Cumulative percent
1	Below 100	4	2.38	
2	101 - 150	37	22.02	24.40
3	151 - 200	70	41.66	66.06
4	201 -250	35	19.64	85.70
5	251 – 300	15	08.92	94.65
6	301 –350	5	02.97	97.62
7	351 – 400	3	01.78	99.40
8	Above 400	1	0.60	100.00
Total		168	100.00	100.00

More than 40 percent of these have 150-200 pages. Only one has more than 400.

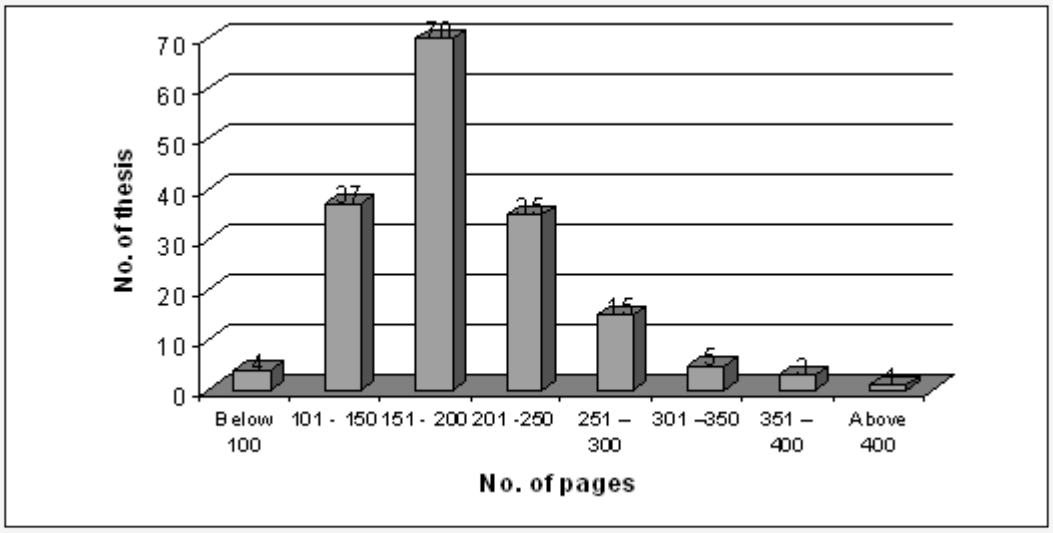


Figure 2: Page-wise distribution of theses

Guideship Pattern

Table 3 reflects the guideship pattern of biochemistry theses.

Table 3: Guideship pattern

Number of guides	No. of theses	Percent
1	145	86.31
2	23	13.69
Total	168	100.00

Nearly all PhD scholars have a single guide, while a few have two.

Productivity of Guides

Table 4 shows the most productive guides in the creation of PhD theses.

Table 4: Most productive guides

Sl. No.	Name	Rank	No. of theses	Percent	Cumulative percent
1	Kurup, P A	1	52	29.38	-
2	Kalesya Raj, R	2	24	13.59	42.97
3	Sudhakaran, P R	3	23	12.99	55.96
4	Vijayalekshmi, N R	4	12	6.78	62.74
5	Saraswathi Devi, K	5	11	6.21	68.95
6	Rajamohan, T	5	11	6.21	75.16
7	Augusti, K T	5	11	6.21	81.37
8	Leelamma, S	6	10	5.65	87.02
9	Vijayammal, P L	7	08	4.52	91.54
10	Venugopal P.Menon	8	07	3.95	95.49
11	Indira, M	9	05	2.82	98.31
12	Abraham, Annie	10	02	1.13	99.44
13	George Philip	11	01	0.56	100.00

Dr. P.A. Kurup, the first head of the department, has guided highest number of PhDs in Biochemistry, with 52, followed by Dr. R. Kalesya Raj second head of the department, who has guided 24 scholars. The third place is occupied by Dr. P. R. Sudhakaran, the present head of the department, who has guided 23 scholars.

Gender-wise analysis of guides

Gender-wise analysis of guides is given in table 5.

Table 5: Gender-wise analysis of guides

Sl. No	Gender	Number	Percent
1	Male	07	53.85
2	Female	06	46.15
Total		13	100.00

The analysis shows that there is no significant difference between the number of male and female guides in the department.

Gender–wise analysis of researchers

Nearly 80 percent of the 168 theses were produced by male scholars.

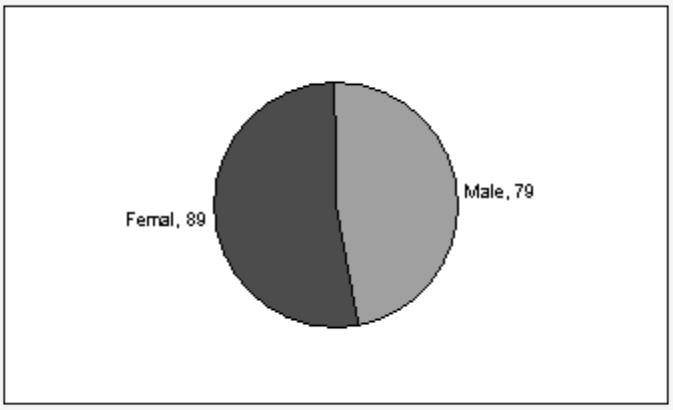


Figure 3. Gender-wise analysis of researchers

Publication productivity

The number of publications included in doctoral theses were analysed to study the publication pattern of researchers.

Table 6. Number of Publications

No. of Publications	Count	Percent	Cumulative percent
Nil	101	60.12	
1- 5	51	30.36	90.48
6-10	13	7.74	98.22
11 -15	03	1.78	100.00
Total	168	100.00	

About 60 percent of researchers do not include the list of their own publications in their theses. About one-third have 1-5 of their own publications listed.

Gender-wise analysis of publication

Table 7. Gender-wise analysis of publication

Sl. No.	Gender	No. of publications	Percent
1	Male	165	55.00
2	Female	135	45.00
Total		300	100.00

Of the 300 publications, 165 (55 percent) were produced by male scholars and 135 (45 percent) by female scholars. Although the thesis productivity of females is higher, the research publication productivity is higher for male scholars.

Distribution of citations in theses

The number of citations in the theses are analyzed to determine the trend of citations and the data is presented in the Table.8.

Table 8. Number of citations in the theses

Sl.No.	Number of citations	Count	Percent	Cumulative percent
1	Up to 100	0	0	
2	101 - 200	36	21.43	21.43
3	201 - 300	55	32.74	54.17
4	301 - 400	48	28.57	82.74
5	401-500	17	10.12	92.86
6	501 - 600	06	3.57	96.43
7	601 - 700	04	2.38	98.81
8	701 - 800	02	1.19	100.00
	Total	168	100.00	

Not a single thesis has fewer than 100 citations. The majority have from 201-300 citations and more than one-quarter have 301-400.

Analysis of citations

Out of 168 theses, 21 were selected for citation analysis. The citation behaviour of researchers and the factors influencing the use of pattern of literature were identified. Citations like books, journals, and other forms of documents given in theses were examined.

Distribution of citations by format

The citations were classified into various bibliographic forms such as journals, books, conference proceedings, and non-print sources.

Table 9. Forms of literature cited

Sl. No	Forms of documents	No. of citations	Percent
1.	Journals	5245	88.75
2.	Books	527	8.92
3.	Conference proceedings	51	0.86
4.	Others (Standards, Reports, Patents, etc.)	87	1.47
Total		5,910	100.00

Journal articles are the most important form of publication cited, with nearly 90 percent.

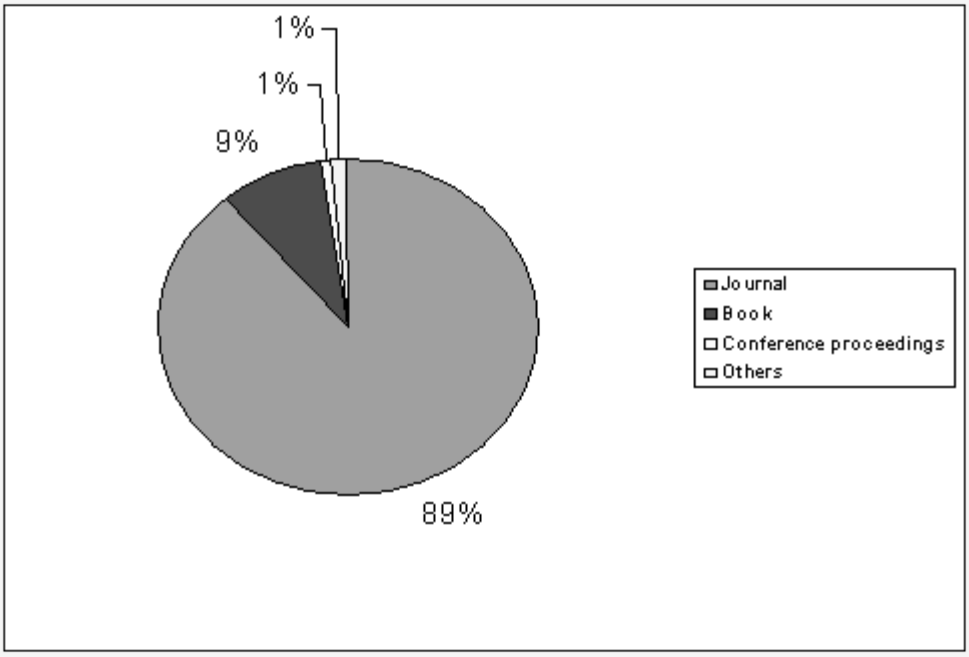


Figure 4. Bibliographic forms of citations

Analysis of citations by language

Nearly 90 percent of citations are in English and all other languages with English translation put together accounted for 672 (11.37 percent) citations. Of these, the major languages used by the researchers are the English translations of Russian, German, and Japanese.

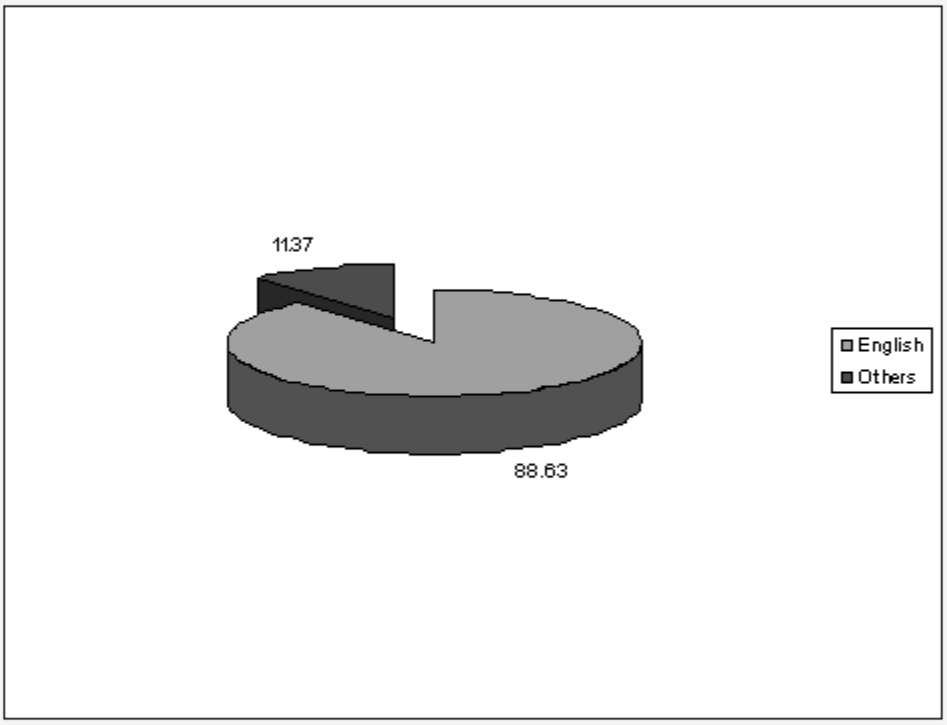


Figure 5. Language wise distribution

Authorship pattern

Table 10. Authorship pattern

Sl. No	Authorship	No. of citations	Percent
1.	Single	1348	22.81
2.	Two	1771	29.96
3.	More than two	2791	47.23
Total		5910	100.00

Slightly more than one-fifth of the citations are single authored, with nearly 30 percent having two authors, and nearly half having three. According to the formula given by Subramanyam (1983) to determine the extent of collaboration in quantitative terms

$$C = \frac{Nm}{Nm + Ns}$$

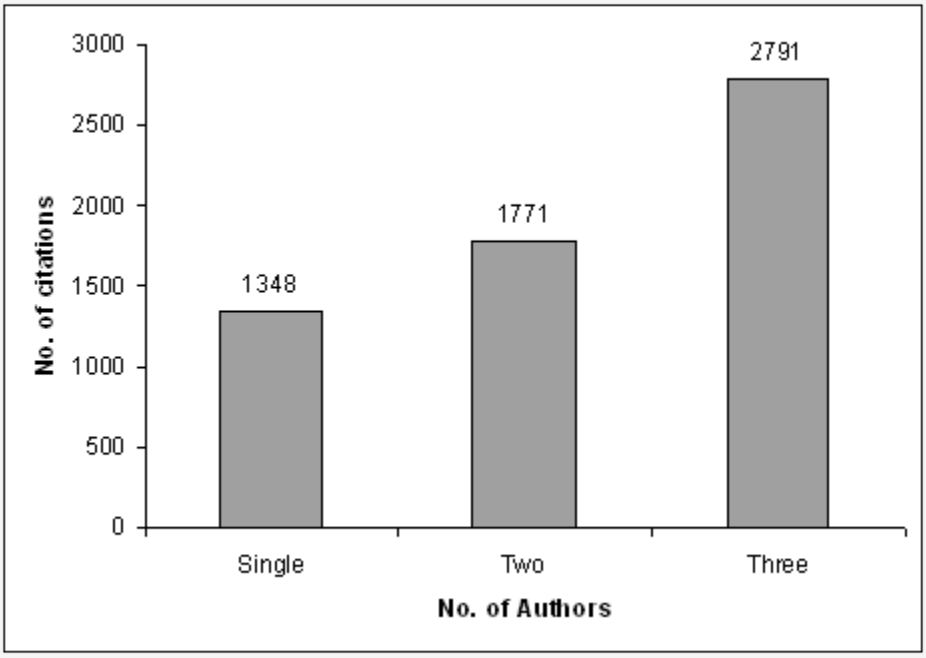
C = Degree of collaboration in a discipline

Nm = Number of multi authored papers

Ns = Number of single authored papers

$$C = \frac{4562}{4562+1348} = \frac{4562}{5910} = 0.778$$

Figure 6. Authorship pattern



Distribution of citations by currency/year of publications

Year-wise distribution is shown in Table 11.

Table 11. Year-wise distribution

Duration	No. of citation	Percent
Before 1951	254	4.30
1951 -1960	387	6.55
1961 -1970	813	13.76
1971 -1980	1359	22.99
1981 -1990	2632	44.53
1991 -2000	465	7.87
Total	5910	100.00

About half the citations are from 1981-1990 and about one-fifth from 1971-1980.

Ranked list of journals

Journals are vital vehicles for disseminating results of current research activities in a field. Therefore, the journals were further analysed in order to determine the most cited.

Table 12. Rank order of journals cited

Sl. No.	Name of periodicals	Country	No. of Citations	Percent
1.	Journal of Biological Chemistry	USA	372	7.09
2.	Journal of Cell Biology	USA	268	5.11
3.	Proceedings of National Academy of Sciences	USA	186	3.55
4.	Journal of Nutrition	USA	158	3.01
5.	Biochemical Et Biophysica Acta	Netherlands	124	2.36
6.	Cell	USA	112	2.13
7.	American Journal of Clinical Nutrition	USA	110	2.08
8.	Diabetes	USA	104	1.98
9.	Atherosclerosis	Ireland	85	1.62
10.	Nature	UK	82	1.56
11.	Experimental Cell Research	USA	79	1.51
12.	Biochemistry Journal	UK	76	1.45
13.	Lancet	UK	73	1.39
14.	Science	USA	68	1.29
15.	Annals of New York Academy of Sciences	USA	64	1.22
16.	Journal of Clinical Investigation	USA	62	1.18
17.	Biochem. Biophys. Res. Communication	USA	57	1.08
18.	Indian Journal of Experimental Biology	India	56	
19.	Proceedings of the Society for Experimental Biology of Medicine	UK	15	0.97
20.	Diabetologia	USA	49	0.98
21.	Developmental Biology	USA	47	0.90
22.	Indian Journal of Biochemistry and Biophysics	India	46	0.88
23.	New England journal of Medicine	UK	45	0.86
24.	Methods in Enzymology	USA	42	0.80
25.	Annual Review of Biochemistry	USA	41	0.78

Table 12 presents a list of 25 core journals frequently used by research scholars in biochemistry, arranged in decreasing order of frequency. *Journal of Biological Chemistry* and *Journal of Cell Biology* occupy the first and second positions in the list. These two journals account for 12.20 percent of total citations for journals.

Ranked list of cited books

A ranked list of the top ten most-cited books is shown in the Table 13.

Table 13: Rank list of books

Rank No.	Author	Title	Year	No. of Citation	Percent
1	Bennet, C.A. & Franklin, N.L.	Statistical Analysis in Chemistry and Chemical Industry	1967	34	6.45
2.	Mair, R.D. and Hall, T.	Organic Peroxides	1977	31	5.88
3.	Furda, F.	Dietary Fibre, Chemistry and Nutrition	1955	30	5.69
4.	Story, J.J.	Dietary Fibre: Basic and Clinical Aspects	1956	28	5.31
5.	Swan, T.	Plant Biochemistry	1965	25	4.74
6.	Wooten, I.D.P.	Micro-analysis in Medical Biochemistry	1964	21	4.55
7.	Von Brand, T.	Biochemistry of Parasites	1973	21	3.98
8.	Cheah, K.S.	Biochemistry of Parasites and Host Parasite Relationship	1976	18.	3.42
9.	Vonkind, D.B. and Klibanov, A.M.	Protein Function	1989	12	2.27
10.	Oliw, E. [et.al.]	Prostaglandin and Related Substances	1983	12	2.27

Statistical Analysis in Chemistry and Chemical Industry is the most cited book with 34 (6.45 percent) citations, followed by *Organic Peroxides*with 31 (5.88 percent).

Conclusion

The study gives interesting and important findings with regards to the various information sources used by scholars. Important areas of research and salient features of research publications are identified. This study allows inferences regarding research approach and citation behaviour to be drawn.

Findings presented in this study can be regarded as a case study. Similar dissertation citation analyses can be done in other subject fields as well as in other institutions. It is hoped that this study will be helpful to researchers who want to identify primary sources of information. Studies of this kind will be helpful for library and information professionals who want to provide suitable services for users and researchers. It can also serve as a feedback to librarians in the selection and acquisition of documents most useful to researchers in biochemistry.

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